A TIS-B Server for Air Traffic Control

Prof. Dr. Erwin Mayer
Fakultät Elektrotechnik und Informationstechnik (E+I)

Badstraße 24
77652 Offenburg
Tel.: 0781 205-225
E-Mail: erwin.mayer@fh-offenburg.de

1960: Geboren in Haslach i.K.
Studium der Informatik an der Universität Karlsruhe und University of Texas (UT), Austin
1987: Diplom
1987–1990: Softwareentwicklung bei der Nixdorf Computer AG, Berlin, im Bereich Verteilte Relationale Datenbanken
1990–1993: Promotion am IBM European Networking Center, Heidelberg, Themenbereiche Multicast-Synchronisationsprotokolle, Computer-Supported Cooperative Work (CSCW)
1994–2006: Projektleiter und Abteilungsleiter bei der COMSOFT GmbH, Karlsruhe. Entwicklung von System- und Anwendungssoftware für die internationale Flugsicherung
Seit 2006: Professor an der Hochschule Offenburg für die Fachgebiete Betriebssysteme und Telematik

Forschungsgebiete: Flugsicherung, Verteilte Systeme, Peer-to-Peer Computing

1.10 A TIS-B Server for Air Traffic Control

Prof. Dr. Erwin Mayer

Introduction

Air traffic control today still works primarily with classical sensors like Primary and Secondary Surveillance Radars (PSR, MSSR, Mode-S) [1]. Upcoming is a new technology, ADS (Automatic Dependent Surveillance), which derives positional information from a Global Navigation Satellite System (GNSS) and distributes this data together with additional information from the on-board Flight Management System (FMS) to other aircraft (air-to-air) and to ADS groundstations (air-to-ground). [2] Because the transmission of the data takes place on a shared broadcasting media, like the 1090 MHz Extended Squitter (ES) channel, the technology is also referred to as ADS-Broadcast (ADS-B).

A lot of modern aircraft, in particular commercial airliners, are already equipped with ADS-B transponders, while older aircraft and in particular smaller aircraft operating under Visual Flight Rules (VFR) will for a significant period of time not yet be installed with this equipment.

Because of the Broadcasting properties of ADS-B, all aircraft equipped with this technology can „see" each other, i.e. they receive ADS-B messages of all other ADS-B aircraft in their proximity. Modern avionics technology takes advantage of this by providing to the pilot an air situation picture on a Cockpit Display of Traffic Information (CDTI).

The role of the CDTI is less the direct safety aspect, which is taken care of by ground-based Air Traffic Control, but the aspect of giving to the pilot an additional „situational awareness" of the airspace he is operating in. [3]

Traffic Information System – Broadcast (TIS-B)

ADS-equipped aircraft (AACs) can see each other but can NOT see Non-ADS-equipped aircraft (NACs) in their vicinity. Therefore the pilot's view of the neighboring airspace through a CDTI is necessarily incomplete. Here is, where the TIS-B (Traffic Information System – Broadcast) technology is motivated. The missing information is being sent by means of TIS-B groundstations „ground-to-air" to the aircraft, acting as a „gap filler" application.

Figure 1.10-1 shows the approach. The input from classical sensors and ADS-B groundstations is conveyed over a Wide Area Surveillance Network, like the European RADNET [4], to an Air Traffic Control Centre (ATCC), where the data is tracked (i.e. smoothed, error-corrected, extrapolated, ..) and prepared for redistribution to the aircraft. A TIS-B Server is the central instance of control for this redistribution, acting as a Time/Space Scheduler (TSS) for a regional network of TIS-B groundstations. The server decides over which of the strategically placed groundstations each of the aircraft is serviced, in which intervals and with which send characteristics.

Under real-time constraints the TIS-B server dispatches Send Requests including the target identification of each of the chosen groundstations , the selected transmitter segment (direction) and the power of transmission, together defining 3D-transmission sectors („cake pies").

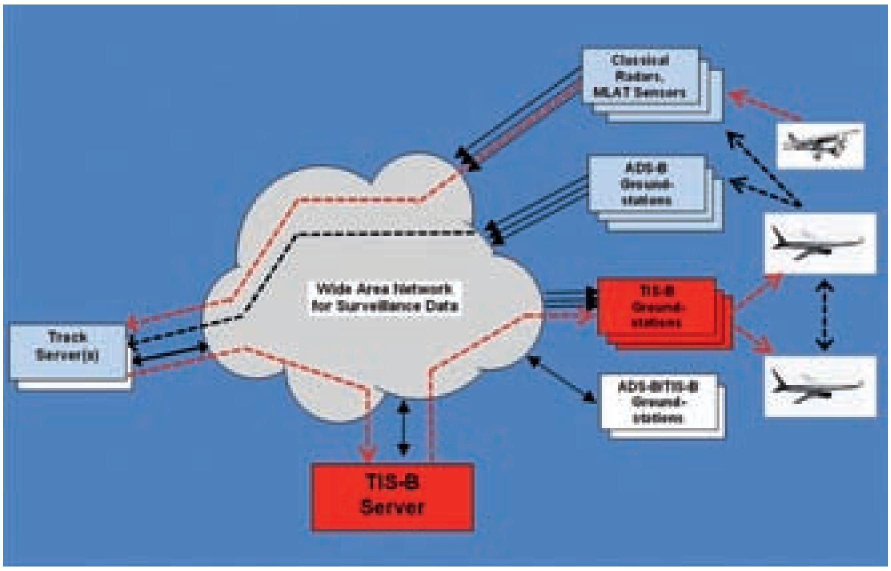

Fig. 1.10-1: *Role of a TIS-B Server in a future mixed sensor scenario for air traffic control*

Requirements for a TIS-B Server

As part of a BMBF (Bundesministerium für Bildung und Forschung)-funded project the University of Applied Science Offenburg (UASO) together with industry partner COMSOFT embarked on developing a prototype TIS-B system solution to demonstrate feasibility and evaluate system characteristics based on various input scenarios and environmental constraints. While COMSOFT develops the hardware and firmware of the TIS-B groundstations, UASO develops the software for the TIS-B Server component. The TIS-B Server is being developed as part of a simulation and test environment for a battery of geographically distributed TIS-B groundstations. Table 1 describes the major requirements of the component. Requirements F1-F3 describes functional requirements, while O1-O3 represents optimization criteria.

As part of the project, the complete set of operational requirements for the TIS-B server component was derived from [5], and models the TIS-B service in such a way that it behaves towards the aircraft much like further genuine ADS-B transponders (i.e. ground-to-air simulating air-to-air).

Optimization Goals

The fulfillment of the optimization criteria are subject to the conditions under which the TIS-B system operates, namely the following input parameters:

- the placement strategy for the set of ground stations in a geographical area
- the geographical characteristics of the groundstation positions (line of sight profiles)
- the type of air traffic (en-route/approach, VFR/IFR, high density/low density)
- the parameters of the functional requirements (update frequency, definition of proximity relation)

Under a given set of parameters and a given real or simulated flight input scenario the output functions (Radio Frequency Load, Load Balancing Factor, Ancillary Functions) of the TIS-B server will be evaluated against criteria O1, O2 and O3. As the optimization criteria are clearly interdependent (e.g. selecting a ground station based on load vs. airspace radio load reduction) a multi-variable optimization has to take place.

No:	Requirement	Functional/Optimization Criteria
1	Realtime Conformance (F1)	The TIS-B Scheduler shall guarantee that all generated reports arrive in time before their scheduled transmission time at the respective ground stations. The reports shall comprise a correct t/x/y/z-extrapolation.
2	Vicinity Reporting (F2)	The TIS-B Scheduler shall ensure that any ADS aircraft receives reports for any Non-ADS aircraft for the time during which the two fulfill a specified proximity relation. The TIS-B server ensures a configurable maximum cyclic update interval for each pair of ADS/Non-ADS aircraft.
3	Non-Interference (F3)	The TIS-B Server guarantees that no two send operations dispatched to two different TIS-B groundstations interfere during their timely propagation with each other in the 3D-overlap of the groundstations‘ send ranges.
4	Radio Frequency (RF) Load Minimization (O1)	The TIS-B scheduler shall minimize the RF load over the airspace service volume. As minimization function shall serve the time integral of air space cells affected by a TIS-B groundstation send operations. As an alternative minimization function shall serve the maximum RF load on any of the specified airspace cells.
5	Ground Station Load Balancing (O2)	The TIS-B scheduler shall ensure an approximately even scheduling between ADS-B groundstations. In case of load level reporting from a ground station, the TIS-B scheduler shall dynamically adapt its scheduling strategy and perform graceful degradation of the TIS-B Service.
6	Ancillary Optimization Criteria (O3)	There exist a range of further optimization criteria, ensuring, e.g., that the transmitter engine is not powered up / powered down too often and that single transponders are not overloaded by too frequent updates.

Tabelle 1 *TIS-B Server top-level requirements and optimization criteria*

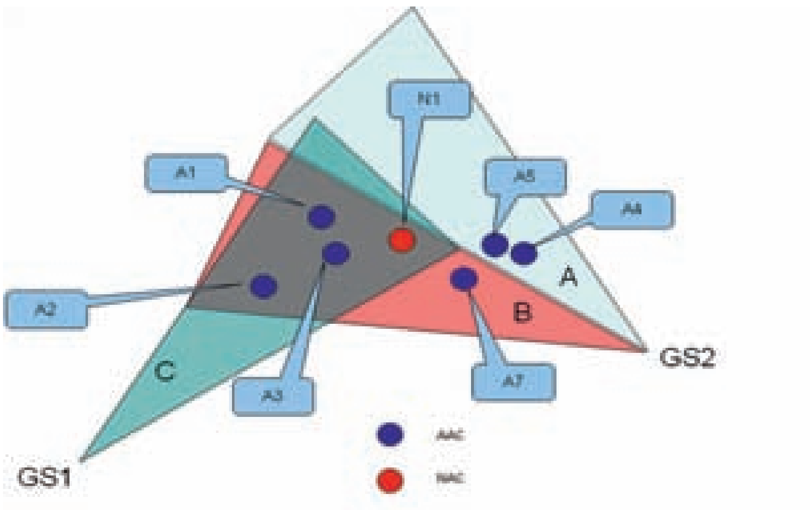

Fig. 1.10-2: *X/Y- traffic optimization for TIS-B groundstation overlap region*

Design

As central element of the TIS-B server a Time/Space Scheduler (TSS) is implemented as a variant of an Earliest Deadline First (EDF) real-time scheduling strategy(F1)[6]. In addition to the standard approach the scheduler has to take into account the geographical nature of the problem with a competition of resources (radio frequency band per air space cell) that is only partial, namely in the intersections of the groundstations (Req F3). Next to the imposed cyclic update requirements there is an aperiodic element, based on the maximum extrapolation time for each individual report. The time of the to-be-transmitted information is ceiled by a maximum age, in order to ensure that the air situation picture is not updated with obsolete information. Because the input of data is asynchronous (the TIS-B server does not know when it will receive new position updates for any of the flights from any of the surveillance sensors), the scheduling has to be dynamic.

Figure 1.10-2 illustrates an example of a micro-optimization implemented by the server in the x/y pane. Clearly, all AAC aircraft (A1-A7) can be reached by 3 send requests (A, B, C) from 2 ground stations (GS1, GS2) using different power levels to inform them about the close NAC aircraft (N1). Assuming there is a need for a status update at approximately the same time for all AACs, the server applies a 2-phase exploration and consolidation algorithm and yields an optimum of 2 send requests (A, B) employing ground station GS2 sector B with maximum power level and GS2'2 A sector with a power level corresponding to the range of A5. This reduces the overall radio frequency load and thereby caters for optimization criteria O1.

Implementation

The TIS-B server prototype is implemented under a SUSE LINUX platform using ORACLE as both a data container and processing engine. A relational database was chosen, because a lot of the system's inherent logic including the proximity relation between AAC and NAC aircraft or the coverage alternatives for optimization of radio frequency load can be modeled ideally employing N:M entity relationships. The major system architecture centers around the Scheduling Component, which is implemented efficiently by PL/SQL stored procedures. The ORACLE kernel is embedded in a JAVA wrapper, that also implements the encoding and decoding of surveillance data. On application level the ASTERIX (All-Purpose Structured Eurocontrol SuRveillance Information Exchange) protocol with its categories 21 (ADS-B data) and 62 (surveillance track data). [7][8] as well as DF18 output format ([5]) is implemented. On transport level a Wide Area TCP/IP network using UDP as transmission protocol is used. Online input data is normally received from a Tracking System in an Air Traffic Control Centre. Figure 1.10-3: TIS-B operation on a prototype surveillance data display using a Mercator projection in replay modus and generated data (green cones are TIS-B groundstations' send events).

Status and Outlook

A TIS-B Server prototype is implemented and currently undergoing integration and system testing. Interface testing from and to the adjacent systems of the cooperation partner were successful. Initial functional testing is taking place using recorded track data of operational traffic in ASTERIX Cat 62.

As an additional test vehicle, a combined ADS-B/MLAT antenna is installed on the roof of the Hochschule Offenburg. It receives live ADS-B data of the air traffic in the South-West German airspace and feeds this data via the UASO's campus LAN to the TIS-B server in the laboratory.

Currently the focus of the project is on the development of a simulation testbed, including test data generators and analysis tools for validating the system against the functional and optimization requirements. Additionally, as a thesis work item, a Google-Earth-based visualization component is under way.

References

[1] Heinrich Mesen, Moderne Flugsicherung, Organisation, Verfahren, Technik, Springer Verlag, 3. Auflage 2004

[2] EUROCONTROL, Automatic Dependent Surveillance Concept, SUR/ET3/ST06.2101/001, 2001

[3] EUROCONTROL CASCADE Program, www.eurocontrol.int/cascade

[4] E. Mayer, RADNET – A network for Air Traffic Control, GI Fachtagung Kommunikation in Verteilten Systemen (KiVS), Chemnitz, 1995

[5] RTCA, Minimum Operational Performance Standards (MOPS) for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B), RTCA DO-260A, Vol1 & 2, 2003

[6] Wörn, Brinkschulte, Echtzeitsysteme, Springer Verlag, 2005

[7] E. Mayer, ASTERIX – The Emerging World-Wide Standard in the Surveillance Domain, ATCA, 43rd Annual Convention, Atlantic City, USA, 1998

[8] EUROCONTROL, ASTERIX, Part 9, Cat 62, SDPS Track Messages, Ed. 1.8, August 2008

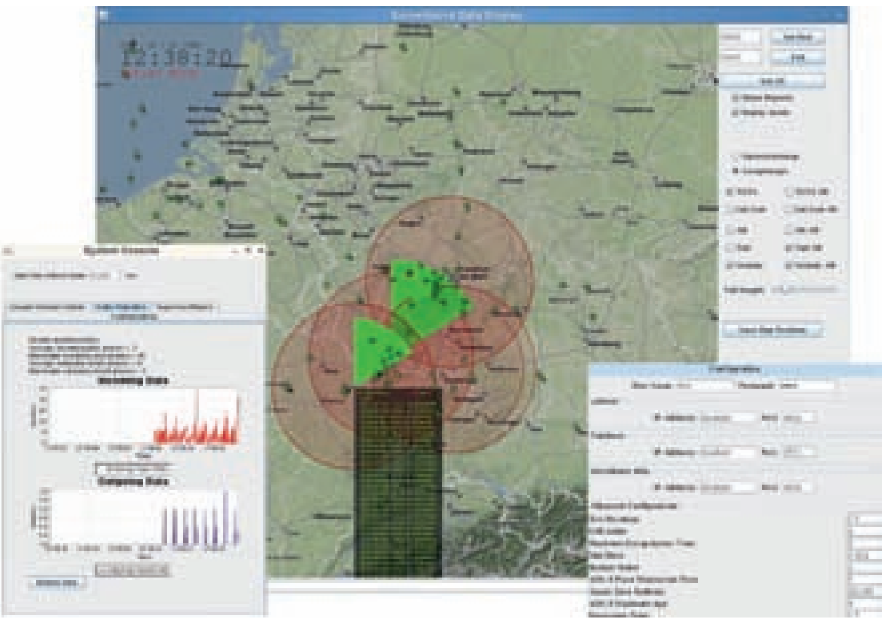

Fig. 1.10-3: *shows an excerpt of the TIS-B servers operational console*